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(54) Antenna arrangement and mobile terminal

(57) The invention relates to an antenna arrangement for a mobile terminal having a stable receiving sensitivity and a symmetric radiation pattern and to a corresponding mobile terminal. The antenna arrangement comprises a loop antenna (410) having an electrical conductor performing an open loop, one end of the electrical conductor being connected to a variable capacitor 411 and the other end being connected to a ground electrode (431), the electrical conductor being further connected to a micrcstrip line 412. The arrangement further comprises a rod antenna (420) and means (414, 415) for attaching said rod antenna to said loop antenna.

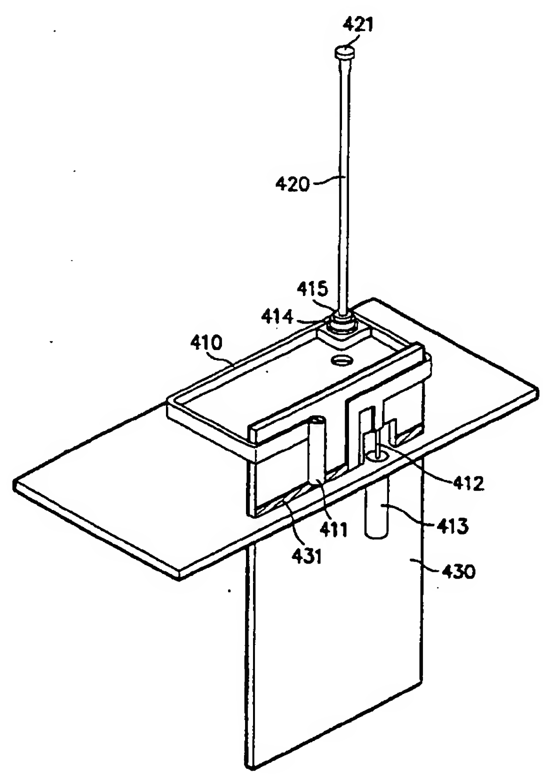

FIG. 3

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Description

[0001] The present invention relates to an antenna arrangement for a mobile terminal, and to a corresponding mobile terminal having said antenna arrangement.

[0002] In general, an antenna apparatus for a mobile terminal consists of a fixed helical antenna and a retractable rod antenna. The helical antenna operates in a retracted state and the rod antenna operates in an extended state.

[0003] FIG. 1 illustrates a conventional antenna apparatus in the extended state and its peripheral circuits, and FIG. 2 illustrates the conventional antenna apparatus in the retracted state and its peripheral circuits. The detailed structure and operation of the antenna apparatus is well disclosed in Korean patent registration No. 107414/1996.

[0004] Referring to FIGs. 1 and 2, the antenna apparatus for a mobile terminal 100 consists of a helical antenna 130 mounted on an upper portion of a housing 301, leaning to one side, and a rod antenna 120 fixed to the housing 301 by an antenna cap 106. The hollow antenna cap 106 has a protrusion 107 formed at an upper, inner wall, through which the rod antenna 120 is inserted. Under the antenna cap 106, a conductive female screw 111 is fixed to the upper end of the housing 301. A cylindrical male screw 109 having a through hole is screwed to the female screw 111. A head of the cylindrical male screw 109 is attached to a lower end of a helical winding 108 inserted into an opening of the antenna cap 106. The antenna cap 106 is fixed to the housing 301 such that a lower end of the antenna cap 106 is fixed to the head of the cylindrical male screw 109. The rod antenna 120 is composed of a polyacetal rod 104, an antenna core line 105 inserted into the polyacetal rod 104, an isolation element 103 with a fixing groove 102 formed at an upper, outer circumference, and a pull 101 formed at an upper end of the isolation element 103. The rod antenna 120 is inserted into the antenna cap 106, passing along a center axis of the helical antenna 130 and the through hole of the cylindrical male screw 109. A lower end of the polyacetal rod 104 is fixed to a stopper 110. In the retracted state of the rod antenna 120, the protrusion 107 formed at the upper portion of the antenna cap 106 is inserted into the fixing groove 102 of the isolation element 103 so that the rod antenna 120 may not be pulled out by itself. In the extended state of the rod antenna 120, the stopper 110 fixed to the lower end of the polyacetal rod 104 is stopped by a plate spring 112 mounted on the through hole of the cylindrical male screw 109. The female screw 111 is connected to a printed circuit board (PCB) 205 by way of a feeding connector 201.

[0005] As illustrated, the antenna core line 105 extends from the stopper 110 to the lower end of the isolation element 103. The rod antenna 120 is made of the polyacetal rod 104 having a good restoring force, and serves as a protection rod for the antenna core line 105. The antenna core line 105 may be made of a silver-plated cooper wire or piano wire, or a superelastic nickel-titanium wire (i.e., shape-memory alloy) having a good restoring force. The electric length of the antenna core line 105 is between $\lambda/4$ and $\lambda/2$ (i.e., approximately 87-174 mm at 860MHz), taking into consideration the vertical length of the housing 301. In practice, the physical length of the antenna core line 105 can be reduced to 132 mm by virtue of a dielectric constant of the polyacetal rod 104. When the vertical length of the housing 301 is very short, a telescoping antenna may be used for the rod antenna 120.

[0006] The helical winding 108 of the helical antenna 130 is made of a silver-plated piano wire having a diameter of 5.6 mm. The electric length of the helical winding 108 is related to the length of the antenna core line 105 of the rod antenna 120. The physical length of the helical antenna 130 is relatively much shorter than that of the rod antenna 120.

[0007] As illustrated, the antenna apparatus is leaned toward one side of the mobile terminal. Therefore, in the retracted state of the rod antenna 120, the overall length of the antenna apparatus is reduced and only the helical antenna 130 radiates a radio signal. In this case, due to the positional asymmetry of the helical antenna 130, the radiation pattem is distorted, reducing the radiation distribution in a specific direction. On the other hand, in the extended state of the rod antenna 120, the overall length of the antenna apparatus is increased, thus improving the radiation characteristic and the communication quality. However, in the event that the antenna apparatus is leaned toward one side of the mobile terminal, the radiation pattem of the antenna apparatus is asymmetrical and the receiving sensitivity may depend on the position of the mobile terminal. In particular, this asymmetrical problem becomes serious in the retracted stated of the rod antenna. Further, an increase in the operating frequency requires an extension in the size of the mobile terminal with respect to the wavelength, which accelerates the distortion of the radiation pattern thereby causing a difficulty in designing a compact mobile terminal.

[0008] It is the object of the present invention to provide a non-directional antenna arrangement for a mobile terminal having a stable receiving sensitivity, and a corresponding mobile terminal.

[0009] This object is solved by the subject matters of claims 1 and 16.

[0010] The invention is advantageous in that it provides an antenna arrangement for a mobile terminal having a symmetric radiation pattern.

[0011] Preferred embodiments are defined by the dependent claims.

[0012] When the antenna apparatus is used in a PCS (Personal Communication Service) band, it is possible to prevent asymmetry of the radiation pattern, thereby improving the communication quality.

[0013] The present invention will become more apparent from the following detailed description when tak-

en in conjunction with the accompanying drawings in which:

FIG. 1 is a diagram illustrating a conventional antenna apparatus in the extended state and its peripheral circuits;
FIG. 2 is a diagram illustrating the antenna apparatus of FIG. 1 in the retracted state and its peripheral circuits;
FIG. 3 is a diagram illustrating an antenna apparatus for a mobile terminal according to an embodiment of the present invention;
FIG. 4 is a diagram illustrating the antenna apparatus of FIG. 3 in the extended state;
FIG. 5 is a diagram illustrating the antenna apparatus of FIG. 3 in the retracted state;
FIG. 6 is a diagram illustrating a current distribution of the antenna apparatus in the extended state;
FIG. 7 is a diagram illustrating a variable capacitor (411) according to a first embodiment of the present invention;
FIG. 8 is a diagram illustrating a variable capacitor (411) according to a second embodiment of the present invention;
FIG. 9 is a diagram illustrating a voltage standing wave ratio (VSWR) of the antenna in the retracted state;
FIG. 10 is a diagram illustrating a voltage standing wave ratio (VSWR) of the novel antenna in the extended state;
FIG. 11 is a diagram illustrating a radiation pattern of the novel antenna apparatus on an azimuth plane in the retracted state;
FIG. 12 is a diagram illustrating a radiation pattern of the conventional antenna apparatus on the azimuth plane in the retracted state;
FIG. 13 is a diagram illustrating a radiation pattern of the novel antenna apparatus on an elevation plane in the retracted state;
FIG. 14 is a diagram illustrating a radiation pattern of the conventional antenna apparatus on the elevation plane in the retracted state;
FIG. 15 is a diagram illustrating a radiation pattern of the novel antenna apparatus on the azimuth plane in the extended state;
FIG. 16 is a diagram illustrating a radiation pattern of the conventional antenna apparatus on the azimuth plane in the extended state; and
FIG. 17 is a diagram illustrating a radiation pattern of the novel antenna apparatus on the elevation plane in the extended state.

[0014] A preferred embodiment of the present invention will be described hereinbelow with reference to the accompanying drawings. In the following description, well known functions or constructions are not described in detail.

[0015] FIG. 3 illustrates an antenna apparatus for a mobile terminal according to an embodiment of the present invention. FIGs. 4 and 5 illustrate the antenna apparatus of FIG. 3 in the extended state and the retracted state, respectively.

[0016] Referring to FIGs. 3 to 5, an antenna apparatus of the invention consists of a rectangular hula hoop antenna 410 and a rod antenna 420. The hula hoop antenna 410 is placed at an upper, inner center of a housing 401 of the mobile terminal. The rod antenna 420, which is retractable and extendible into and from the housing 410, is disposed at a given corner of the hula hoop antenna 410. The hula hoop antenna 410 is supported by a printed circuit board (PCB) 430. Further, the hula hoop antenna 410 has an end connected to a variable capacitor 411 on the PCB 430 and another end connected to a ground plate 431 of the PCB 430. For feeding and arrangement of the antenna apparatus, the ground plate is removed at the upper portion of the PCB 430. A microstrip line 412 united with the hula hoop antenna 410 is connected to a low noise amplifier (LNA) 413 in a transceiver of the mobile terminal. A conductive fixing member 414 having a through hole is fixed to a corner of the hula hoop antenna 410, and a cylindrical fixing member 415 is inserted into the through hole of the conductive fixing member 414. The rod antenna 420 is movably restricted to the housing 401 by the cylindrical fixing member 415. The rod antenna 420 is composed of a polyacetal rod, an isolation element with a length NC, and a pull 421. The polyacetal rod has a conductive core line (not shown) formed along a center axis. Lower ends of the conductive core line and the polyacetal rod are fixed to a stopper (not shown).

[0017] In the retracted state, a lower end of the rod antenna 420 reaches a retraction point (not shown) in the housing 401, passing through the cylindrical fixing member 415. In the extended state, the pull 421 of the rod antenna 420 reaches to an extension point (not shown) over the housing 401. In that event, the topper fixed to the lower end of the polyacetal rod is stopped by the cylindrical fixing member 415.

[0018] The rod antenna 420 made of a metal wire has a length L1 such that it can serve as a $\lambda/2$ antenna in the extended state. The hula hoop antenna 410 is made of a metal strip or wire. The rod antenna 420 is coated with a nonconductive material so that it may not be coupled to the hula hoop antenna 410 in the retracted state. Further, the rod antenna 420 is so thick that it contacts the hula hoop antenna 410 and cannot be pulled out from the cylindrical fixing member 415 in the extended state.

[0019] In this antenna apparatus, the length ($2 \times h2 + 2 \times h3$) and the height h1 of the hula hoop antenna 410 and the variable capacitor 411 serve to improve a matching characteristic. Therefore, the antenna apparatus does not require a separate matching circuit by feeding a radio signal to the hula hoop antenna 410 using the microstrip line 412. Actually, it is possible to obtain an input impedance of approximately 50Ω by ad-

justing the height of the hula hoop antenna 410 or moving a feeding point right and left.

[0020] FIG. 6 illustrates the current distribution of the antenna apparatus in the extended state. As stated above, the rod antenna 420 is decoupled from the feeding point in the retracted state, so that it does not serve as a radiating element. Accordingly, a symmetric current distribution is given as shown in FIG. 6. For this symmetric current distribution, a radiation pattern on the azimuth plane is measured to be approximately circular.

[0021] Referring back to FIGs. 3 to 5, the conductive fixing member 414 is placed at a comer of the hula hoop antenna 410, where the current distribution is relatively lower than other places. That is, the rod antenna 420 is placed at a given position of the hula hoop antenna 410, having a relatively low current distribution.

[0022] FIG. 7 illustrates the variable capacitor 411 according to a first embodiment of the present invention. As illustrated. the variable capacitor 411 is composed of a screwed cylinder 500 and a screw 510 inserted into the screwed cylinder 500. A capacitance of the variable capacitor 411 can be varied by screwing the screw 510 up and down.

[0023] FIG. 8 illustrates the variable capacitor 411 according to a second embodiment of the present invention. As illustrated, the variable capacitor 411 is composed of a printed circuit board 431 having a plurality of patches 520 each connected to adjacent ones by a patch connection line 530. The capacitance of the variable capacitor 411 can be varied by cutting the patch connection line 530 at desired positions.

[0024] FIGs. 9 and 10 illustrate voltage standing wave ratios (VSWRs) of the antenna apparatus in the retracted state and the extended state, respectively.

[0025] FIG. 11 illustrates the radiation pattem of the antenna apparatus according to the invention on an azimuth plane in the retracted state, and FIG. 12 illustrates a radiation pattem of the conventional antenna apparatus on the azimuth plane in the retracted state. For the antenna apparatus according to the invention, a gain difference between the maximum and minimum gains on the azimuth plane is 9dB which is much lower than that of the conventional antenna apparatus. The low gain difference will decrease the directivity of the antenna apparatus, providing the improved communication quality and the stable receiving sensitivity.

[0026] FIG. 13 illustrates the radiation pattem of the antenna apparatus according to the invention on an elevation plane in the retracted state, in which the peak gain appears at around 90°. However, the conventional antenna apparatus has the peak gain at around 140°, as shown in FIG. 14. Since the current distribution of the hula hoop antenna 410 is substantially symmetrical, the antenna apparatus according to the invention can maintain the symmetrical radiation pattern even in the retracted state of the rod antenna 420. In addition, since the rod antenna 420 is so constructed as to serve as a $\lambda/2$ antenna in the extended state, the increase in length of the antenna apparatus may increase the antenna gain, thereby improving the communication quality.

[0027] FIG. 15 illustrates the radiation pattem of the antenna apparatus according to the invention on the azimuth plane in the extended state, in which the gain different between the maximum and minimum gains is 5dB. However, as shown in FIG. 16, the conventional antenna apparatus has the gain difference 8dB which is higher by 3dB than that of the antenna apparatus according to the invention.

[0028] FIG. 17 illustrates the radiation pattem of the antenna apparatus according to the invention on the elevation plane in the extended state, in which the peak gain appears at around 0-90°.

[0029] The antenna arrangement according to the invention is preferably used in a PCS band.

[0030] In conclusion, the antenna apparatus has a stable receiving sensitivity and the non-directivity, by securing the symmetrical radiation pattem.

Claims

1. Antenna arrangement for a mobile terminal, comprising:

    a loop antenna (410) having an electrical conductor performing an open loop, one end of the electrical conductor being connected to a variable capacitor (411) and the other end being connected to a ground electrode (431). the electrical conductor being further connected to a microstrip line (412);

    a rod antenna (420); and

    means (414, 415) for attaching said rod antenna to said loop antenna.

2. The arrangement according to claim 1, wherein said loop antenna is a rectangular hula hoop antenna, and said rod antenna is attached to a comer of said hula hoop antenna.

3. The arrangement according to one of claims 1 or 2, wherein the loop antenna is placed at an upper, inner center of a housing (401) of the mobile terminal, and said rod antenna is extendible and retractable from and into the housing.

4. The arrangement according to one of claims 1 to 3, wherein said means for attaching said rod antenna to said loop antenna comprises:

    a conductive fixing member (414) having a through hole; and

    a cylindrical fixing member (415) inserted into

said through hole, said rod antenna passing along a centre axis of the cylindrical fixing member.

5. The arrangement according to one of claims 1 to 4, wherein said variable capacitor and said ground electrode are located on a printed circuit board (430).

6. The arrangement according to one of claims 1 to 5, wherein said loop antenna is made of a metal wire.

7. The arrangement according to one of claims 1 to 5, wherein said loop antenna is made of a metal strip.

8. The arrangement according to one of claims 1 to 7, wherein said rod antenna is attached to said loop antenna where the current distribution over said loop [illegible] minimum.

9. The arrangement according to one of claims 1 to 8, wherein said rod antenna comprises a wire coated with [illegible] material so that said rod antenna and said loop antenna are decoupled in a retracted state of said rod antenna.

10. The arrangement according to one of claims 1 to 9, wherein said rod antenna is a $\lambda/2$ antenna in an extended state of said rod antenna.

11. The arrangement according to claim 10, wherein said rod antenna has a thickness suitable for contacting said loop antenna in the extended state of said rod antenna

12. The arrangement according to one of claims 1 to 11, wherein said variable capacitor comprises:

   a screwed cylinder (500); and

   a screw (510) inserted into the screwed cylinder;

   wherein the capacitance of the variable capacitor can be varied by screwing the screw.

13. The arrangement according to one of claims 1 to 11, wherein said variable capacitor comprises:

   a printed circuit board (431),

   a plurality of patches (520) formed on the printed circuit board; and

   a patch connection line (530) for connecting the patches;

   wherein the capacitance of the variable capacitor can be varied by cutting the patch connector line at given positions.

14. The arrangement according to claims 1 to 13, wherein said loop antenna and said rod antenna operate in a PCS (Personal Communication Service) band.

15. The arrangement according to one of claims 1 to 14, wherein said loop antenna has an input impedance depending on the height (h1) thereof.

16. Mobile terminal comprising an antenna arrangement according to one of claims 1 to 15.

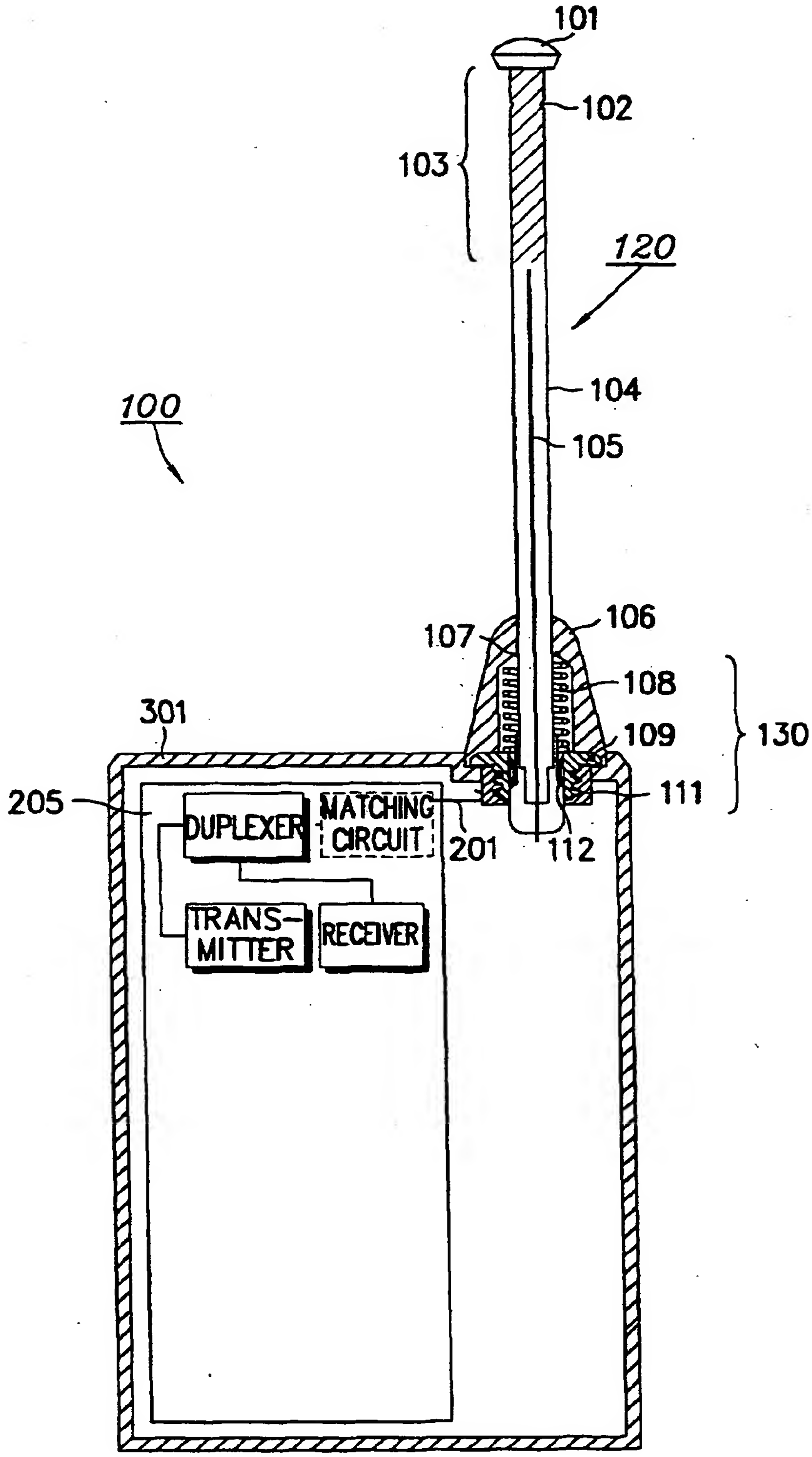

101
102
103
120
104
100
105
106
107
108
109
130
301
205
DUPLEXER
MATCHING CIRCUIT
111
201
112
TRANS-MITTER
RECEIVER

FIG. 1

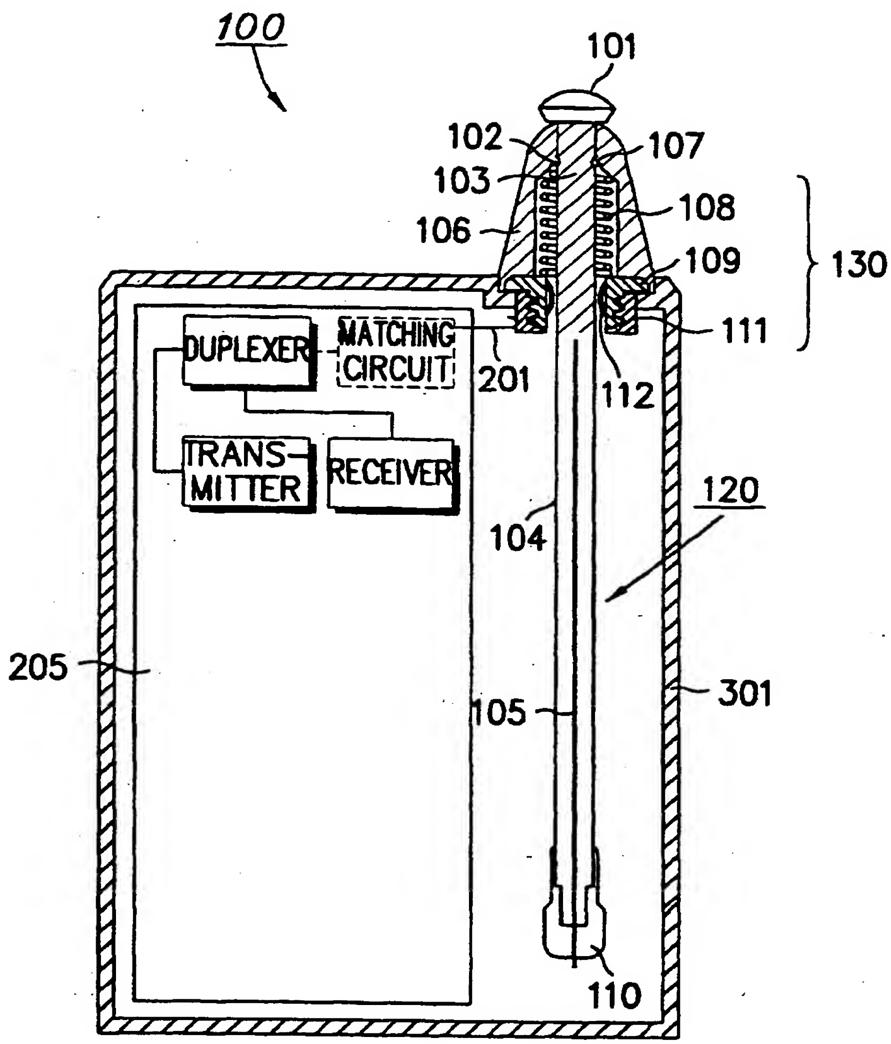

100
101
102
107
103
108
106
109
130
111
DUPLEXER
MATCHING
CIRCUIT
201
112
TRANS-
MITTER
RECEIVER
120
104
205
105
301
110

FIG. 2

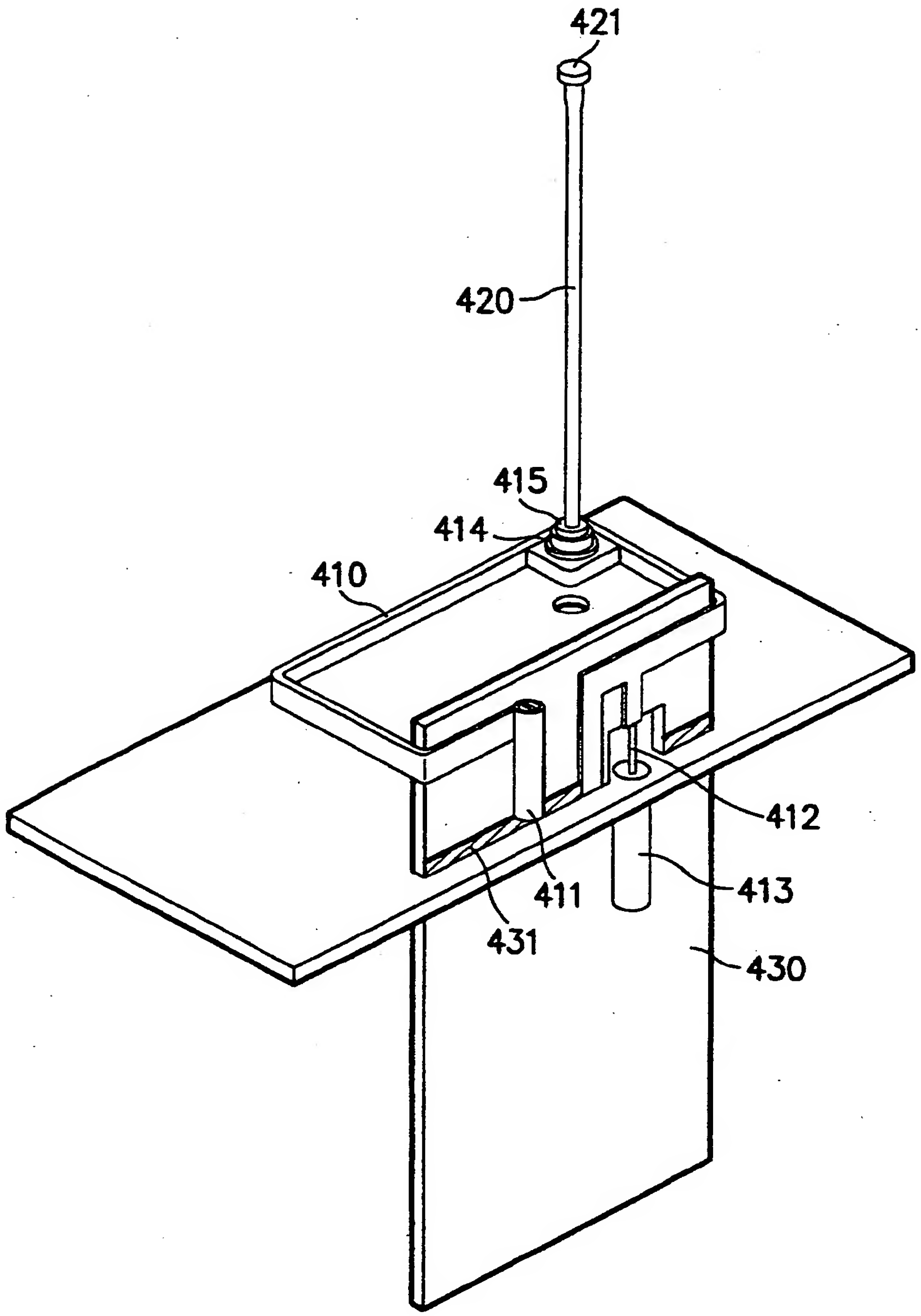


FIG. 3

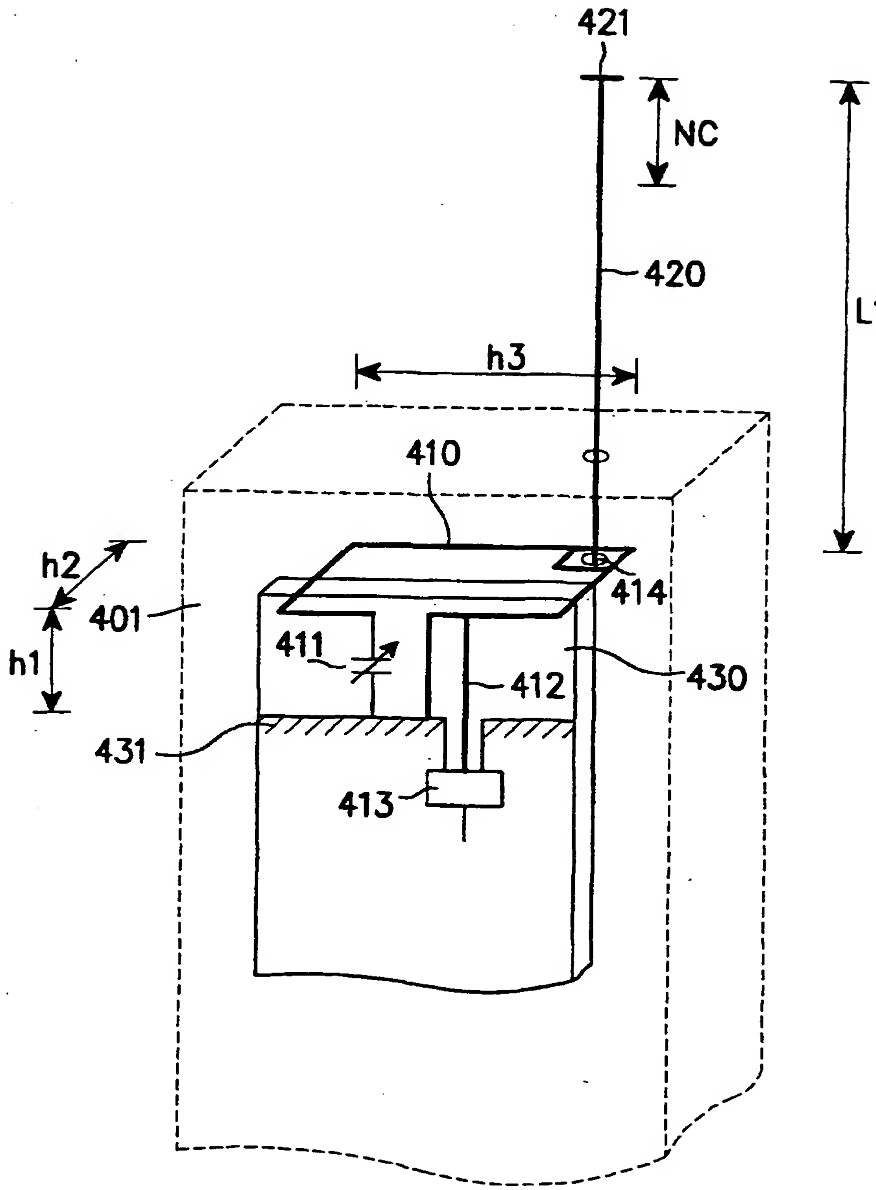


FIG. 4

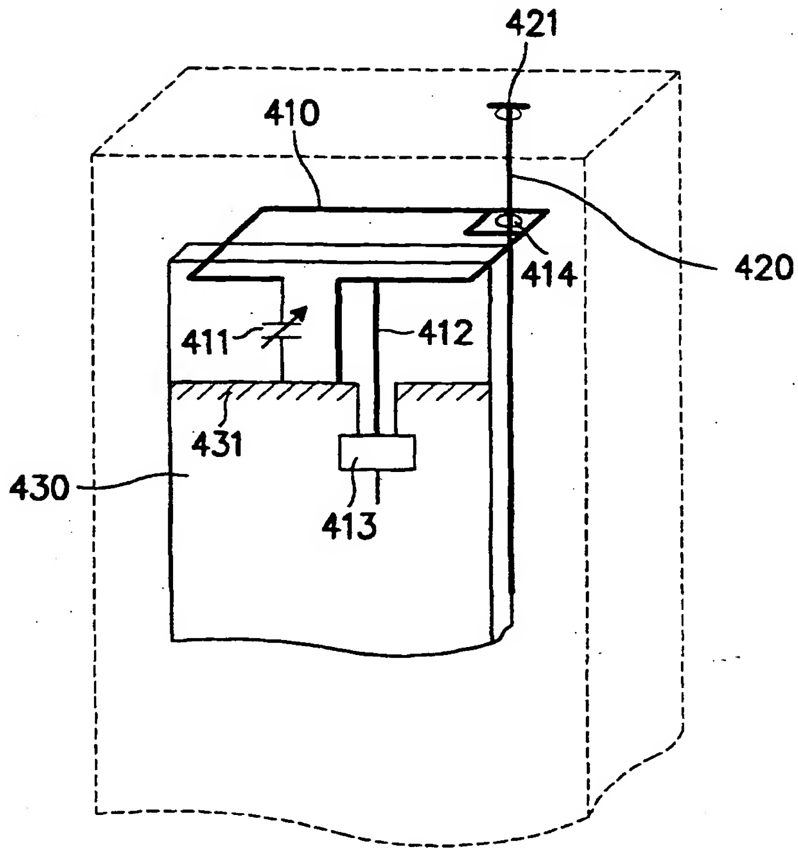


FIG. 5

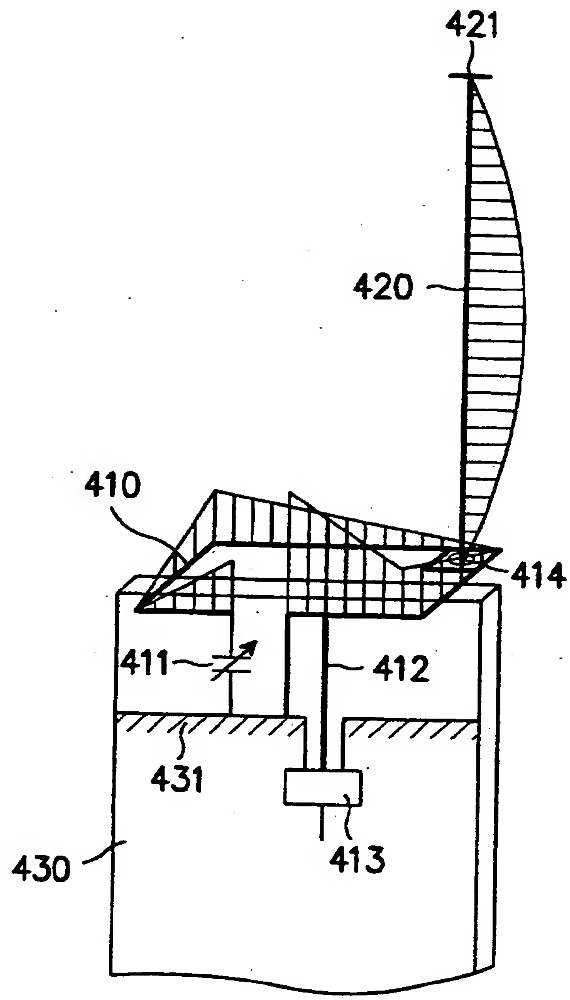


FIG. 6

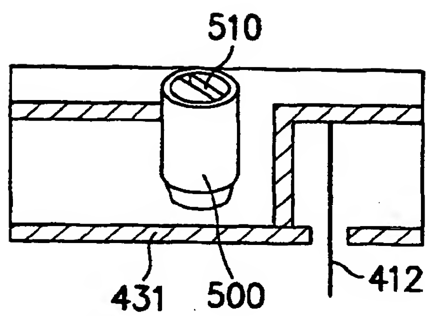


FIG. 7

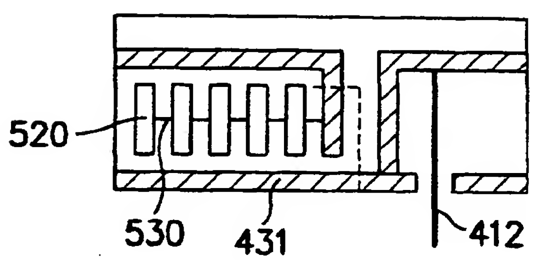
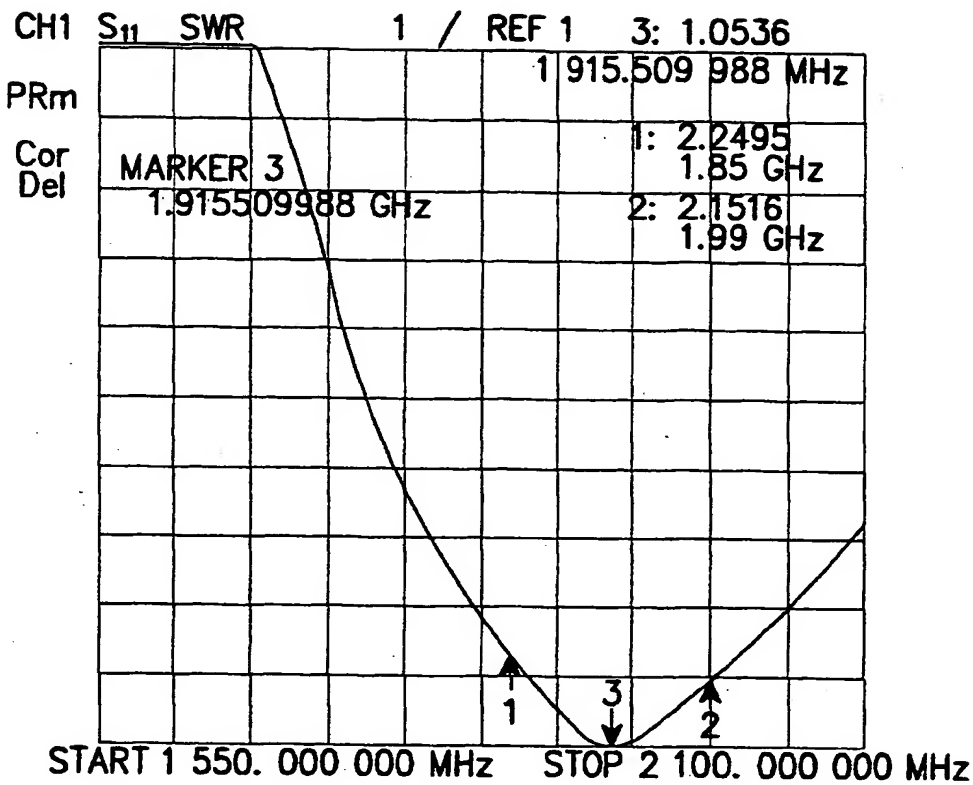


FIG. 8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1 915.509 988 MHz
PRm
Cor
Del
MARKER 3
1.915509988 GHz
1: 2.2495
1.85 GHz
2: 2.1516
1.99 GHz
1
3
2
START 1 550. 000 000 MHz STOP 2 100. 000 000 MHz

FIG. 9

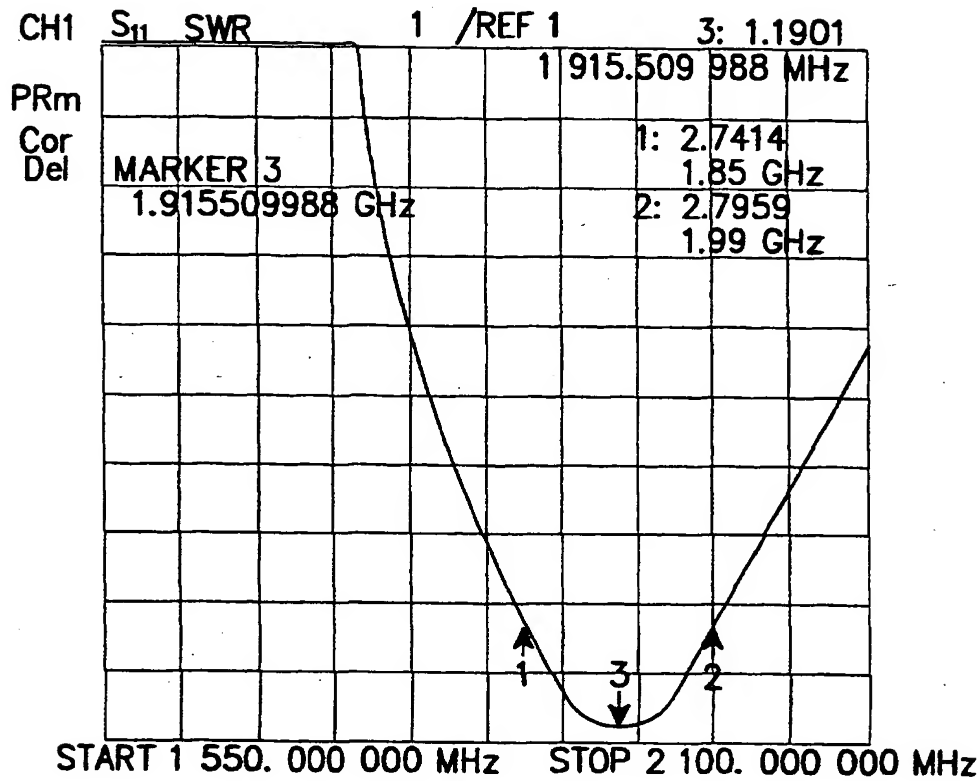
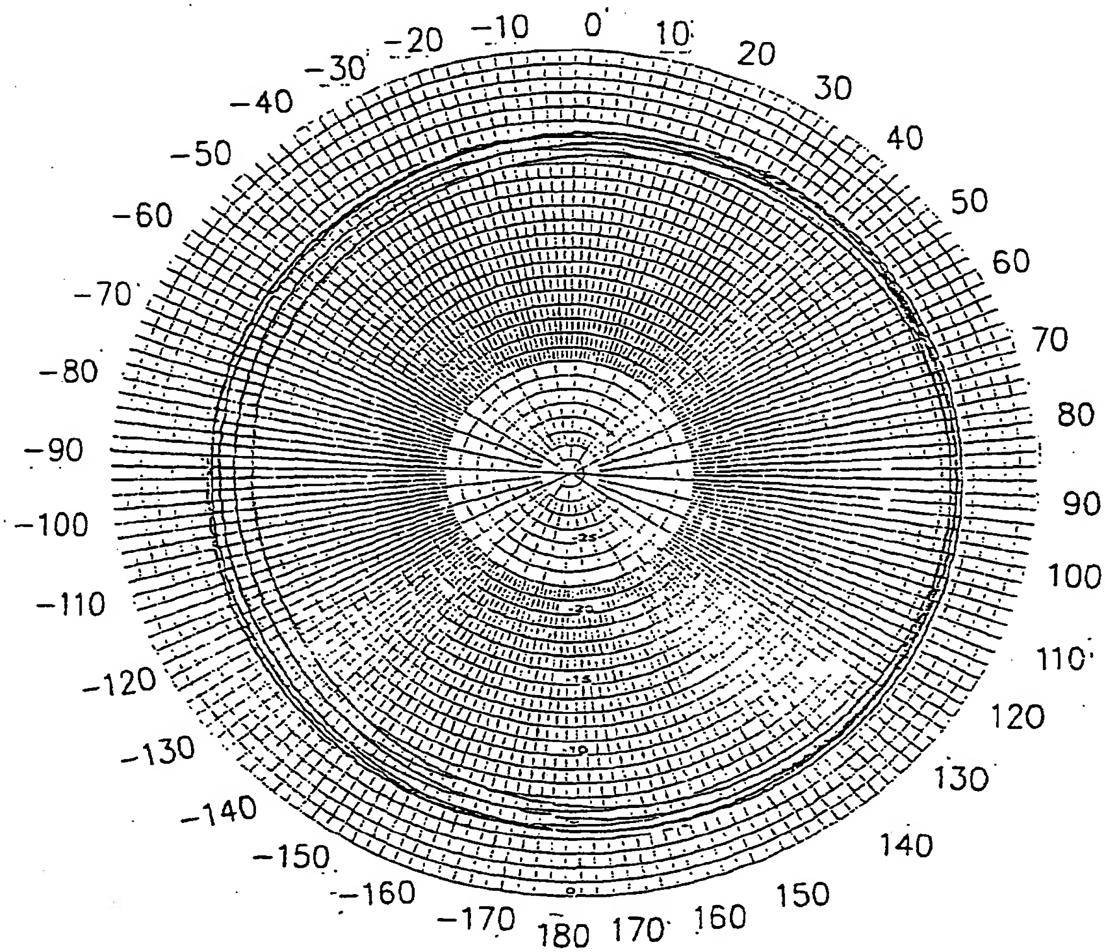

CH1 S11 SWR 1 /REF 1 3: 1.1901
1 915.509 988 MHz
PRm
Cor
Del
MARKER 3
1.915509988 GHz
1: 2.7414
1.85 GHz
2: 2.7959
1.99 GHz
1
3
2
START 1 550. 000 000 MHz
STOP 2 100. 000 000 MHz

FIG. 10

CHANNEL :1710–1990M

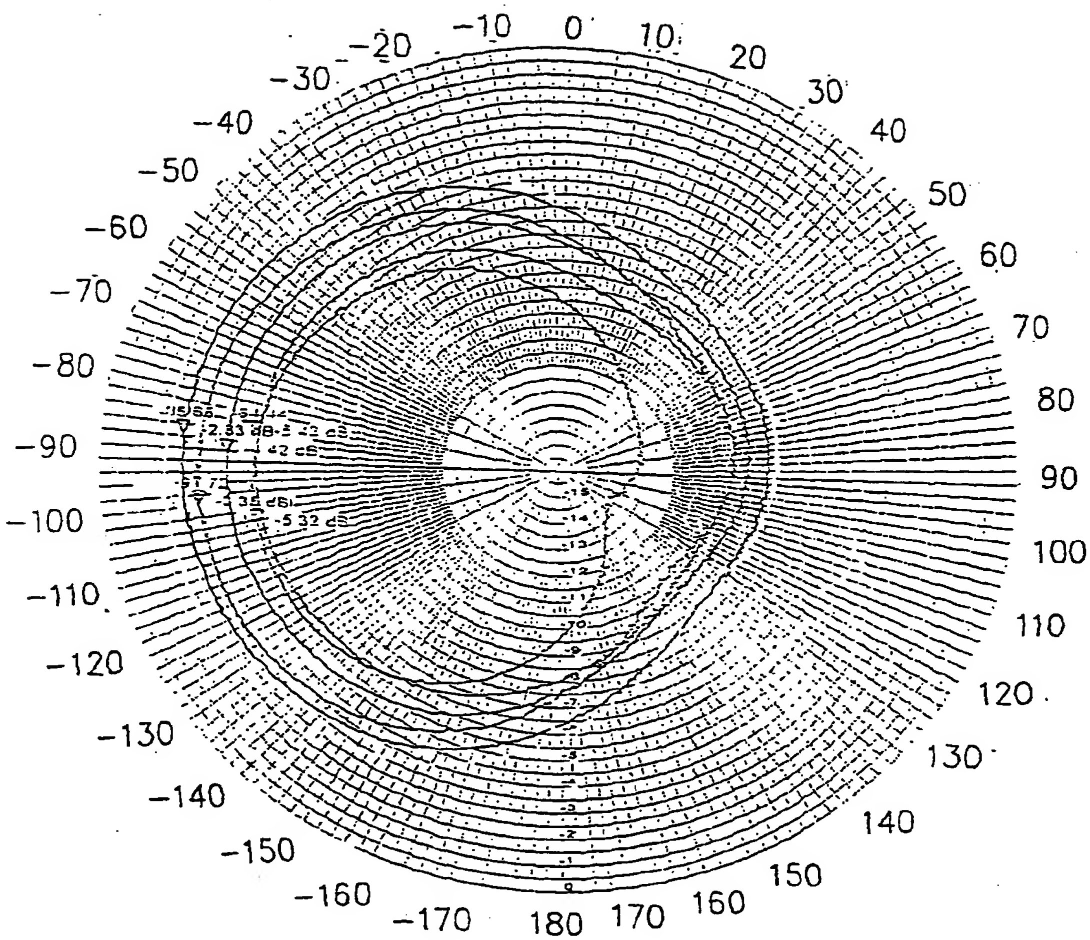


OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 11

CHANNEL :1710–1990M

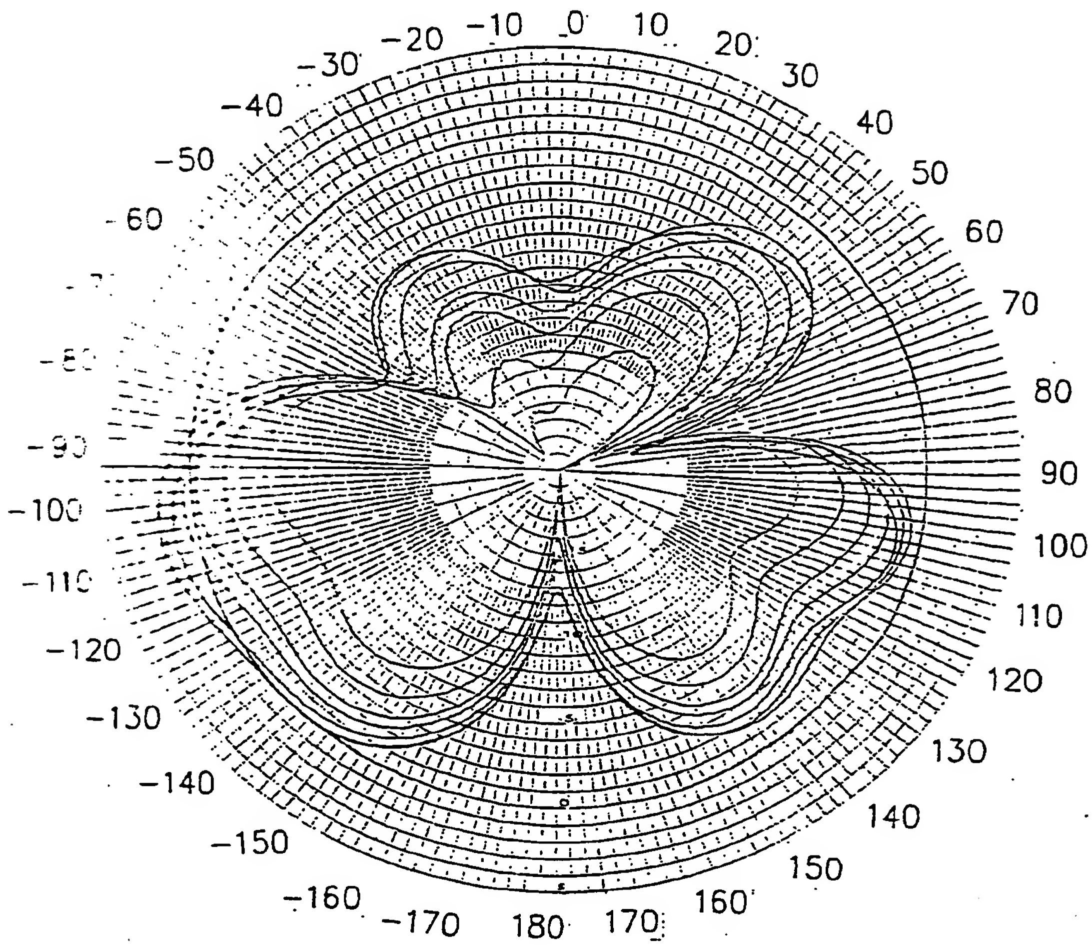


OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 12

CHANNEL :1710–1990M

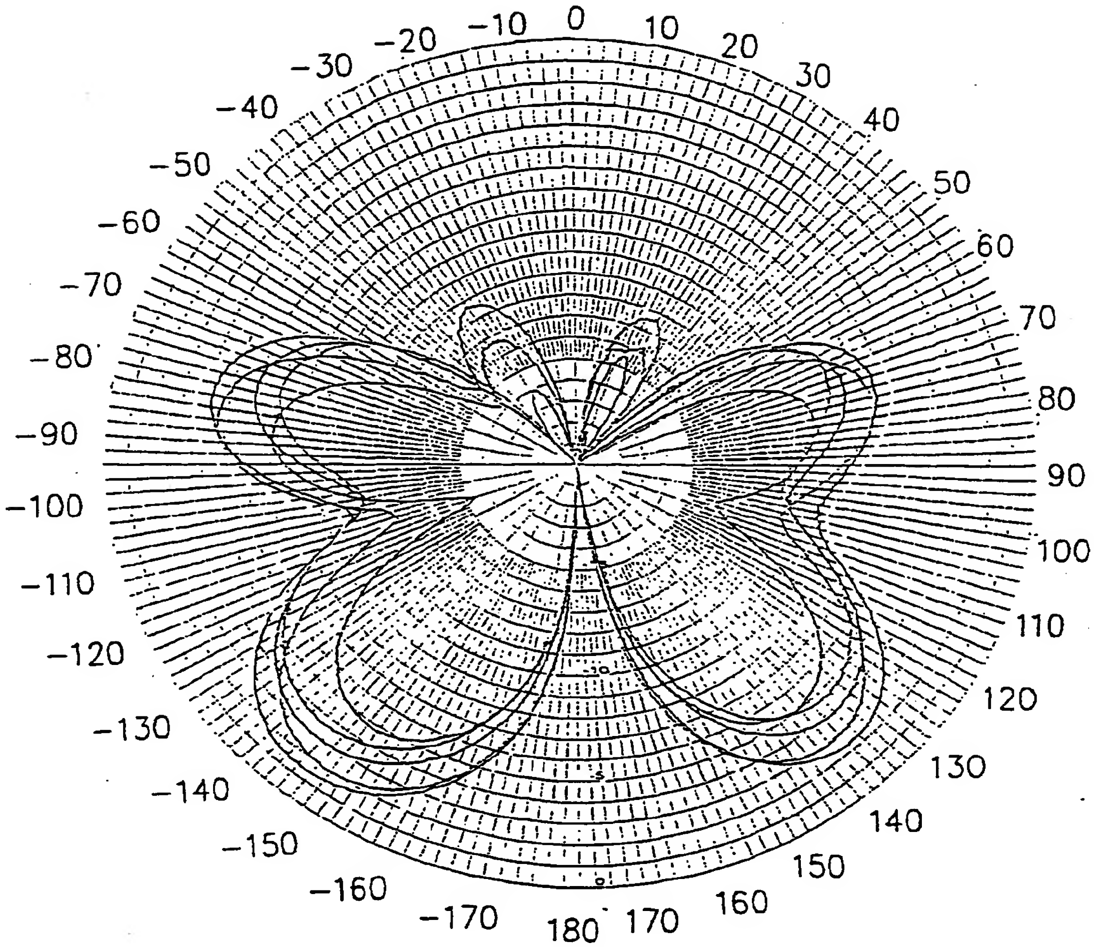


OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 13

CHANNEL :1710-1990M

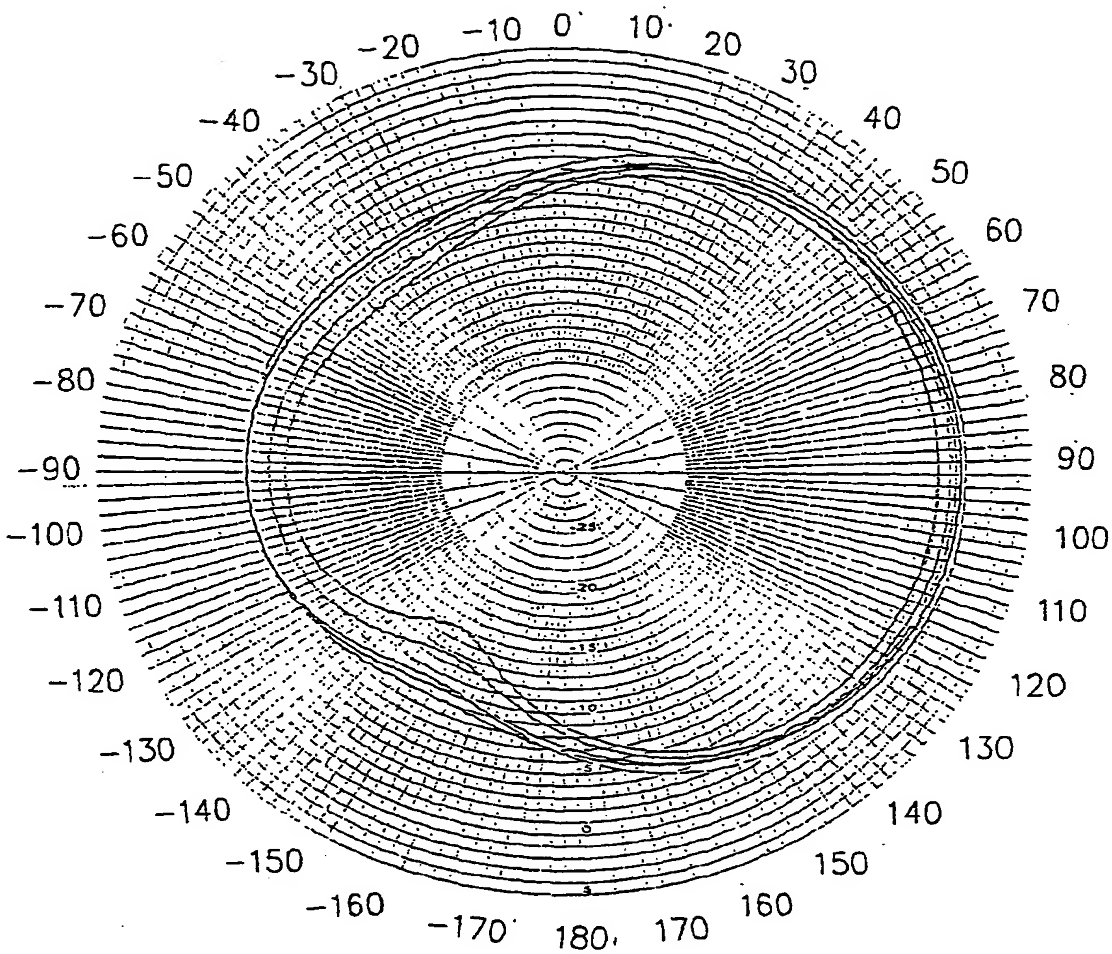


OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 14

CHANNEL :1710–1990M

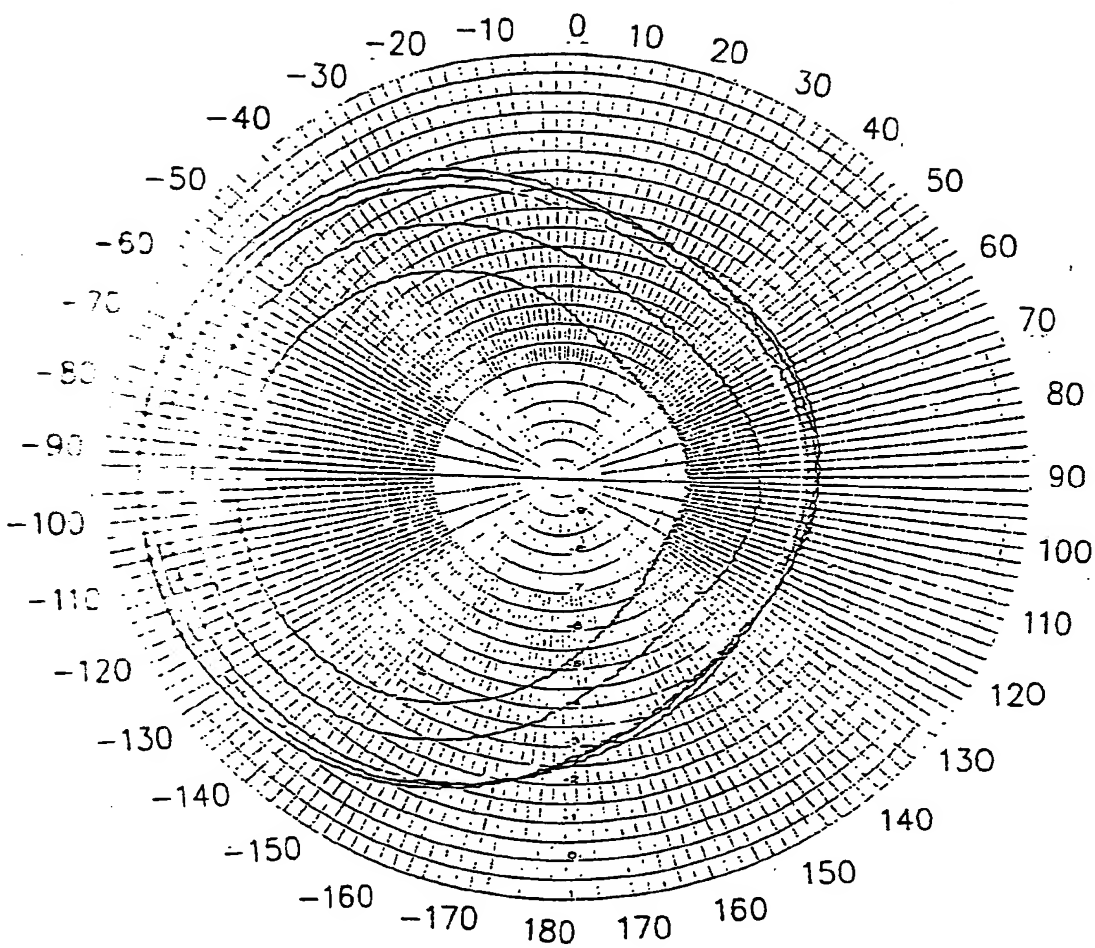


OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 15

CHANNEL : 1710–1990M

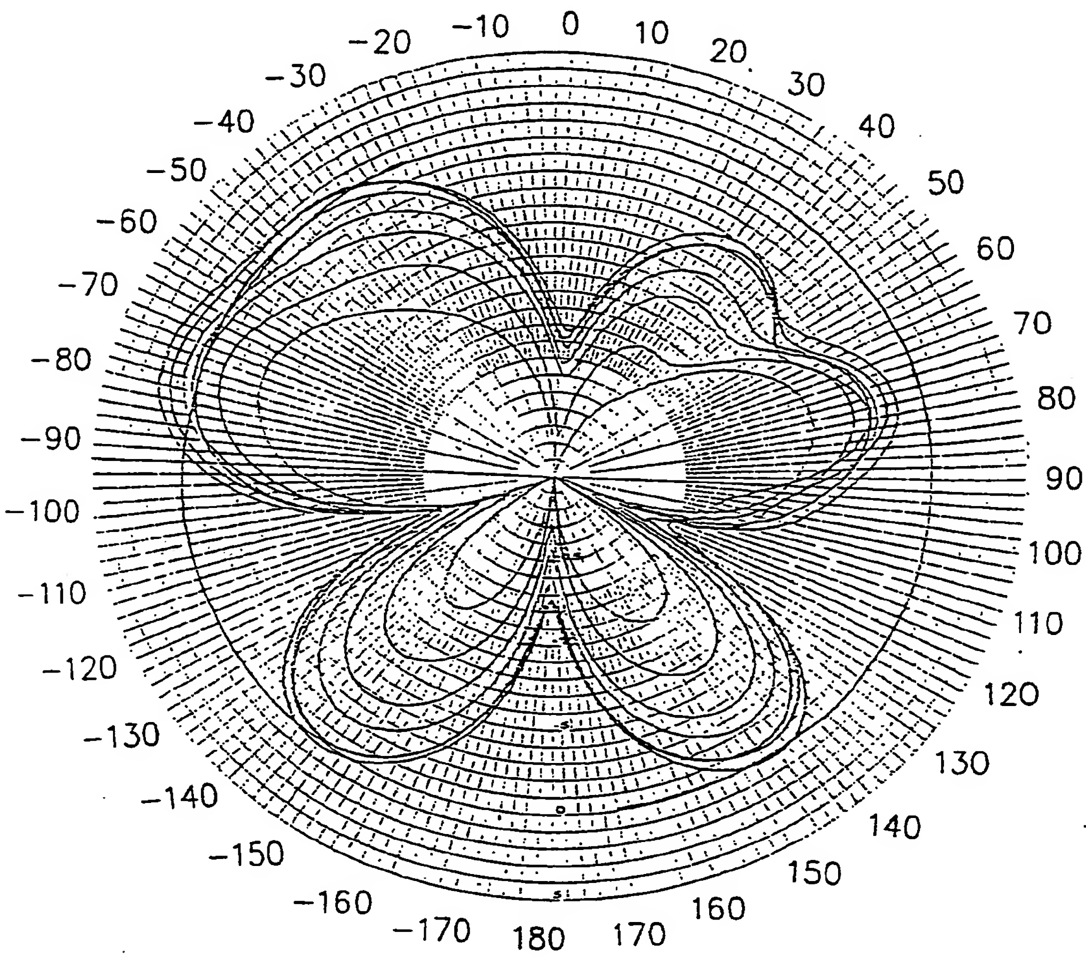


OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 16

CHANNEL :1710–1990M



OVERLAYS
FREQUENCY : 1.850 GHz
FREQUENCY : 1.880 GHz
FREQUENCY : 1.910 GHz
FREQUENCY : 1.930 GHz
FREQUENCY : 1.960 GHz
FREQUENCY : 1.990 GHz

MAGNITUDE (dB)
VS.
AZIMUTH (DEG)

FIG. 17

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(54) **Antenna arrangement and mobile terminal**

(57) The invention relates to an antenna arrangement for a mobile terminal having a stable receiving sensitivity and a symmetric radiation pattern and to a corresponding mobile terminal. The antenna arrangement comprises a loop antenna (410) having an electrical conductor performing an open loop, one end of the electrical conductor being connected to a variable capacitor 411 and the other end being connected to a ground electrode (431), the electrical conductor being further connected to a micrcstrip line 412. The arrangement further comprises a rod antenna (420) and means (414, 415) for attaching said rod antenna to said loop antenna.

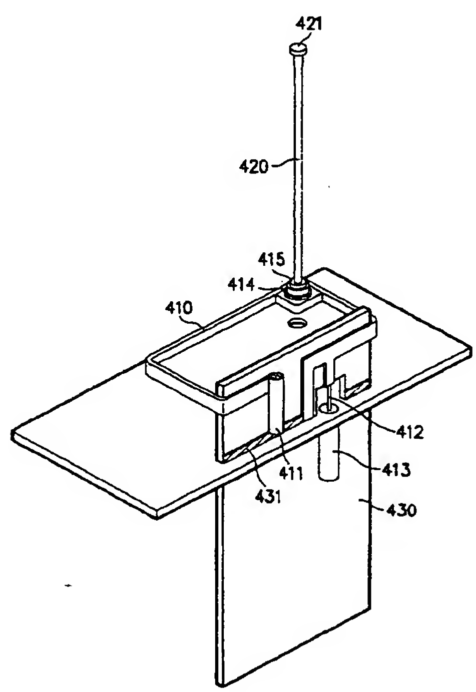

FIG. 3

EP 0 945 917 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 10 3892

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Place of search	Date of completion of the search	Examiner
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X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

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